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NAVAL POSTGRADUATE SCHOOL
Monterey, California

Report of the Office of Naval Research USA-China Conference on Shallow Water Acoustics, December 19-21, 1995

by

Ching-Sang Chiu
Warren W. Denner

January 1997

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

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Under the sponsorship of the Office of Naval Research, the first joint USA-China Conference on Shallow-Water Acoustics was held in December 1995 at the Naval Postgraduate School, Monterey, CA. The conference objective was to identify and discuss the outstanding research topics in shallow-water acoustics which are of common interest of both countries and which might form the basis for a collaborative field program in the seas of China. Participants included acoustilians and oceanographers from both countries, specializing in shallow-water acoustics and coastal ocean monitoring. This report summarizes the tutorial presentations, the deliberations of the working groups, and a plan of action recommended collectively by all the participants.

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Abstract

Under the sponsorship of the Office of Naval Research, the first joint USA-China Conference on shallow-water acoustics was held in December 1995 at the Naval Postgraduate School, Monterey, California. The conference objective was to identify and discuss the outstanding research topics in shallow-water acoustics which are of common interest to both countries and which might form the basis for a collaborative field program in the seas of China. Participants included acousticians and oceanographers from both countries, specializing in shallow-water acoustics and coastal ocean monitoring. This report summaries the tutorial presentations, the deliberations of the working groups, and a plan of action recommended collectively by all the participants.

1 Background/Objectives

Chinese scientists have been conducting underwater acoustic field studies in shallow water for nearly two decades. Some of their results have been published in the Journal of the Acoustical Society of America. Additional work has been published in English in the proceedings of various international conferences, and in translations of the Chinese Journal of Acoustics. This literature establishes that they have developed some unique experimental techniques and excellent analytical methods in shallow-water acoustics research.

The United States has a strong recent interest in shallow water acoustics and has initiated accelerated programs of research. The Office of Naval Research has sponsored one such experiment in the Barents Sea in 1992 and is currently sponsoring more extensive experiments in the Mid-Atlantic Bight. When visiting China in January of 1995, the Principal Investigator (PI) of this project suggested the possibility of a similar experiment in the Yellow Sea. The Chinese were interested in the possibility of participating in such a joint experiment, and we collaborated with us in writing a strawman document. As a first step, we agreed that if funding could be identified, a conference should be held in the United States to assess the scientific rational and logistic issues for such an experiment. This is a typical approach used by scientists to develop scientific objectives and a detailed experimental plan.

Under the sponsorship of the Office of Naval Research, a four-day conference was held in December 1995 at the Naval Postgraduate School, Monterey, California. The conference objectives were:

1. To identify and discuss the outstanding research topics in shallow-water acoustics which are of common interest to both countries and which might form the basis for a joint experimental program.
2. To discuss and assess the scientific approaches and logistic issues for such an experiment.
3. To assess the available technology to support the experiment effort.
4. To identify potential sites for the experimental program and discuss the environmental conditions.
5. To establish a dialog between Chinese and US scientists interested in shallow-water acoustics.

Participants included acousticians and oceanographers from both countries, specializing in shallow-water acoustics and coastal ocean monitoring. Carefully structured, the conference began with tutorial presentations, followed by working group discussions and their deliberations. The tutorial presentations embarked on seven topical areas: recent and planned experiments in shallow water, modeling shallow-water sound propagation, bottom interaction research, volume interaction research, oceanographic support, remote-sensing support, and technology for shallow-water acoustics research. To maximize scientific information exchange and to facilitate the subsequent discussions in the working groups, presenters in each topical area typically included one US participant and one Chinese participant. Each presentation was followed by a short period of questions, answers and comments. Four working groups (labeled as Volume Interaction, Boundary Interaction, Technology, and Oceanography) were chartered to identify scientific objectives, technical approaches, logistic issues, equipment, potential sites, and oceanographic support that are important to the design of a comprehensive field study. Inter-group communications were enabled by rovers. The conference was concluded with a discussion session involving all the participants, who collectively recommended a plan of action.

The outline of the remainder of this report is as follows: In Sec. 2, the contents of the tutorial presentations are briefly described. The recommendations of the working groups are incorporated in Sec. 3. Conclusions are given in Sec. 4 which include a summary of the accomplishments and a discussion of the plan of action. The conference agenda, list of members in each working group, and a list of attendees are also included in the appendices of this report.

2 Summary of Presentations

In an attempt to maximize scientific information exchange and to facilitate the subsequent discussions in the working groups, seven different topical areas were selected as the focal points for the formal presentations. These topics were:

- Recent and Planned Experiments in Shallow Water
- Modeling Shallow Water Acoustic Propagation
- Bottom Interaction Research
- Volume Interaction Research
- Oceanography Support for Shallow Water Acoustics Research
- Remote Sensing Support for Acoustics Research
- Technology for Shallow Water Acoustics Research

Typically, at least one US participant and one Chinese participant were involved as presenters in each topical area. An exception is noted in the topical area of "Remote Sensing Support for Shallow Water Acoustics Research," in which only a single presentation was given. Each presentation was followed by a short period of questions, answers and comments.

2.1 Recent and Planned Experiments in Shallow Water

(Presenters: Dr. James F. Lynch and Prof. Zhang Ren-He)

Two presentations on recent and planned US and Chinese experiments, by Lynch and Zhang respectively, opened the dialog between the Chinese and US participants and set the theme for the remainder of the conference. Having been involved in several ONR-sponsored, multi-institutional, acoustics experiments in shallow water in recent years, Lynch provided an overview of the 1992 Barents Sea Polar Front (BSPF) Experiment, the 1995 Shallow Water Acoustics Random Medium (SWARM) Experiment, and the upcoming Shelfbreak PRIMER Summer and Winter Experiments. Unique to these recent and planned US experiments is that they contain simultaneous acoustic and oceanographic measurements designed to study the variability and coherence of the propagation of low-frequency sound in a complex shelf environment. Additionally, the BSPF and Shelfbreak PRIMER Experiments were also designed to test the feasibility of tomographically mapping shallow-water sound-speed structure using a combination of fixed sound sources and modeforming vertical-line hydrophone arrays. This feasibility was successfully demonstrated in the BSPF Experiment. Being able to properly account for acoustic mode coupling in both the forward and inverse problems was a critical element for the success in the Barents Sea. Lynch's presentation brought out some of the issues that are presently of interest to the US research community. These include the impact of shelfbreak frontal variability, linear internal waves, and nonlinear internal soliton packets on sound propagation and scattering on the continental shelf.

In his presentation on recent and planned Chinese experimental effort, Zhang noted that the Institute of Acoustics, Chinese Academy of Sciences, began research in shallow-water acoustics in the early 1960's. Their field studies have primarily been carried out in the Yellow Sea with focuses on the measurements of sound propagation, reverberation, ambient noise, and spatial coherence. In the early years, the Chinese experiments were unsophisticated in that each was generally carried out to investigate a single scientific issue. However, Zhang indicated that significant progress has been made. Comprehensive experiments with multiple objectives have been conducted recently. An example of such an experiment in the Yellow Sea in July 1991 was described. In this experiment, two research vessels were involved, deploying suspended short-aperture vertical hydrophone arrays, a sparse horizontal hydrophone array, and electronic and explosive sound sources, to study transmission loss, pulse propagation, vertical and horizontal coherence as well as reverberation. Zhang highlighted some of the experimental results, showing strong dependence of vertical coherence on range, frequency, and source and receiver depths in the presence of a strong summertime thermocline. In the coming two years, two similarly comprehensive summer experiments have been planned by Zhang and his Chinese colleagues to further their investigations of the various acoustic issues in the Yellow Sea where some of the world's strongest vertical gradients predominate.

2.2 Modeling Shallow Water Acoustic Propagation

(Presenters: Prof. Zhang Ren-He and Dr. William Kuperman)

Zhang reported that the Chinese modeling work, at present, focuses on propagation, reverberation, ambient noise, and spatial coherence in stratified and almost-stratified shallow-water environments. This is in close synchronization with their experimental effort. Some of the their modeling approaches were discussed. In particular, the normal-mode method with a generalized phase-integral approximation developed by Zhang for predicting transmission loss has been validated with data. In addition, a ray-mode technique with beam displacement has been used to efficiently model pulse propagation. Reverberation and coherence models based on average laws were also reviewed. Applications of these models in conjunction with data in the estimations of some sea-surface and sediment acoustic parameters were discussed.

Kuperman started his presentation with a discussion of the unique aspects of a shallow-water environment. He pointed out that due to the thinness of the waveguide subject the acoustic energy to constantly interacts with the sea surface and sea bottom. Thus, accurate modeling requires that the physics of boundary interaction as well as the acoustic properties of the boundaries be properly accounted for. Kuperman then proceeded with an overview of the hierarchy of acoustic models. Normal-mode, spectral, and parabolic equation models and their applications in calculating propagation, noise and reverberation in both range-dependent and range-independent shallow-water waveguides were reviewed. The accuracy of the various models was shown by comparing to benchmark solutions. Interesting model results included the indication of the existence of optimal frequencies, which have also been experimentally observed. Kuperman concluded his talk by summarizing some of the latest and future thrusts in model developments in the US. These include treatments of fully three-dimensional environments, elastic/poroelastic media, and realistic fluctuating media.

2.3 Bottom Interaction Research

(Presenters: Dr. George Frisk, Prof. Jin Gouliang, Mr. Shihong Zhou, and Prof. Guan Dinghua)

Drawn from recent literature, Frisk provided a systematic review of the acoustic techniques that have been developed for the characterization of the seabed in shallow water. The characterizations is typically in terms of the compressional and shear wave speeds, compressional and shear wave attenuations, density, and boundary roughness. Frisk grouped the various techniques into five categories and cited example publications and results from each category. The five categories are: full field inversion methods, interface wave inversion techniques, modal inversion methods, crosshole tomographic techniques, and high-frequency acoustic characterization.

Jin focused his presentation on the estimation of the reflection and scattering coefficients using direct measurement methods at high frequencies and mode-based inverse techniques at low frequencies and low grazing angles. He stressed that the seabed may alternatively be characterized using only these two coefficients. Although these coefficients are phenomenological and do not describe the physical structure of the sediment, they provide enough information for the purpose of predicting sound propagation and the reverberation intensity in the shallow water column. Estimates of the reflection and scattering coefficients from experimental data collected in the Yellow Sea were presented.

Zhou reported the progress of his laboratory studies of seabed acoustics. He has built a scaled model in which he could set up as many as seven layers of material representing sediments of different properties. He plans to use this scaled model to study the interaction of the acoustic energy with the sub-bottom structure and to validate numerical propagation models and inverse methods which will be used for the interpretation of field data.

Helpful to the planning and design of acoustic experiments, Guan summarized historical information on the distribution of bottom sediment and mineral provinces in the Bohai, Huanghai, and East China Seas. The sediments were classified by reflection of vertical incident sound pulses and the properties inferred from core samples.

2.4 Volume Interaction Research

(Presenters: Prof. Guan Dinghua, Dr. Nick Makris, Prof. Qui Xinfang, and Dr. Yan Jin)

In addition to summarizing the sediment type and distribution in the seas of China, Guan also provided an overview of Chinese research in volume and surface interaction. He pointed out that volume and surface interaction research in China has focused on surface gravity waves, bubbles and small particles, internal waves, sound speed distributions, biologics, and sound absorption. In particular, he illustrated experimental results on the spatial coherence of the sound field in shallow water and the impact of shallow-water internal waves and solitons on sound transmission. He further highlighted some of the non-acoustic research in China in ocean characterization. SAR and optical remote sensing techniques for mapping the surface wave directional spectrum were discussed.

Using the statistical Cramer-Rao bound, Makris assessed the quality and efficiency of different volumetric parameterization methods and addressed experimental design issues. Parameterizations by empirical orthogonal functions (EOF's) and cartesian cells for ocean mesoscale features and long internal waves for finescale structure were investigated. He suggested that the optimization of experimental design can be achieved by examining the variations in the estimation error bound with signal to noise ratio, experimental geometry, and other design-related factors.

Qiu discussed frequency and direction selective attenuation of sound propagation and reverberation in the Yellow Sea, suggesting that fishes such as anchovies and bluespotted

mackerels and their migration routes might offer an explanation to the observed direction-dependent loss increases near 1300 Hz. Qiu also discussed his laboratory apparatus and resonator method which he used to refine measurements of sound absorbtion due to the chemical relaxation of Boric acid in seawater.

Yan discussed measurements and analysis of the fluctuation of pulse travel time due to internal waves in the Yellow Sea. The measurements used explosive charges and a drifting vertical receiving array. Modal travel-time fluctuation as a function of frequency was examined using modal beamforming and correlation techniques in conjunction with bandpass filtering. He plans to extend the analysis of the fluctuation to include the dependence on the strength of the thermocline and the directionality of the internal wave field.

2.5 Oceanography Support for Shallow Water Acoustics Research

(Presenters: Dr. William Jobst and Prof. Gan Zijun)

Jobst presented an overview of the Mission of the Naval Oceanographic Office, and the tools that they use to carry out that mission. He discussed the survey ships and some of the onboard equipment used to collect data from around the world's oceans. One of NAVOCEANO's unclassified digital data tools, the Generalized Digital Environmental Model (GDEM), was described. Data from GDEM and other unclassified databases for the Yellow Sea and surrounding waters were shown to illustrate how data can be presented. Satellite data (AVHRR) and numerical model simulations of the same area were shown.

Gan gave a comprehensive overview of the physical oceanography of the continental shelf of the East China and Yellow Sea. His presentation was well prepared. This included a discussion of the seasonal changes in the circulation and water property distributions. He discussed the role of the monsoon winds and the Kuroshio Current system on the East China and Yellow Sea. He brought out the existence of inversions of temperature and salinity in the mid water column. The temperature inversion appears to be a common feature of the central Yellow Sea and East China Sea during the winter months, and the latter during the summer months. Gan attributed this to convective mixing during the winter months. The information he presented is useful in determining the acoustical properties and their variability in season.

2.6 Remote Sensing Support for Acoustics Research

(Presenter: Dr. Shi Ping)

Shi discussed remote sensing research in China as well as the research vessel SHI YAN 3 (Experiment 3) which is operated out of the South China Sea Institute of Oceanology at Guangzhou. Chinese scientists work with SAR to determine wave spectra, and to study frontal dynamics. Other studies take advantage of the altimeter on Geosat and TOPEX Poseidon to investigate sea surface slopes and wind waves. In addition, they work with Landsat visible data, NOAA AVHRR, and Ocean Color data. There are several downlink sites in China. He made a list of the types of remote sensing data that he thought would be needed to support an acoustic experiment. He showed some sea surface temperature fields derived from satellite (AVHRR) data.

2.7 Technology for Shallow Water Acoustics Research

(Presenters: Dr. Li Ping and Dr. Robert Spindel)

To begin, Li discussed the development and testing of a new digital satellite sonobuoy system designed and built in China. He described the buoy, its construction, and use in field programs. The present capability as well as planned improvements of this sonobuoy system were discussed. The planned improvements include lowering power consumption and increasing sampling rate, in situ data storage, and clock precision. He then discussed their approach to building vertical hydrophone arrays, a wide band cylindrical transducer with a resonance frequency of 650 Hz, and a temperature profiler (thermistor chain) using 12 channels and internal digital recording. He also described some of the recording and analysis equipment used in their acoustic experiments.

Spindel discussed some of the technologies that has been applied in shallow water acoustic experiments in the United States. He built his presentation around the theme "the key to shallow water acoustics is not acoustics, it is oceanography!" The key technologies that he discussed were environmental data, computers and modeling, modern oceanographic and acoustical instrumentation, and use of satellite data.

3 Summary of Working Group Recommendations

The writeups provided by the chairs and co-chairs of the four working groups, summarizing the discussions and deliberations, are incorporated in this section. Names of the members in each working group can be found in Appendix B.

3.1 Boundary Interaction Working Group

In their discussion, this group focused on possible boundary interaction experiments that could be carried out in a '96 pilot experiment in the Yellow Sea. The group felt that it was critical to identify a natural laboratory in the Yellow Sea in which the geoacoustical properties of the sediment could be characterized with high resolution and accuracy. Of primary importance are; the compressional wave speed as a function of position, the compressional wave attenuation as a function of position and frequency, and the density as a function of position. Of secondary importance are the shear wave speed and attenuation. It was suggested that the following techniques be used to initially characterize the acoustic properties of the sediments in a one-week long pilot experiment:

- Box Coring - The analysis of sediment samples obtained with box cores will provide information about the surficial sediments.
- Sub-bottom Profiling - A "boomer" source in the 1-10 kHz range will provide information about the stratigraphy of the upper tens of meters of sediment.
- Modal Mapping and Inversion - A CW source towed from a moored vertical line array will, when combined with DGPS navigation, create a two-dimensional array that measures the modal behavior in both depth and range (modal mapping). Two-dimensional beamforming and modal inversion methods will then be used to infer the geoacoustic properties.
- Reflection/Reverberation Experiments - An explosive source and hydrophone(s) suspended from the ship will be used in monostatic configuration to measure the reverberant field in the shallow water waveguide. These measurements can be used to infer both the scattering strength and the reflectivity of the seabed.

In addition to these techniques, piston coring and seismo-acoustic interface wave measurement methods will be explored for possible use in the follow-on large-scale experiment. The seismo-acoustic methods are particularly useful in extracting shear properties.

A interesting suggestion by this group was that winter may be the best time to study bottom interaction in shallow water because of the benign, near-isovelocity character of the water column at that time of year. One drawback, however, is the increased probability of rough sea states which cause increased rough surface scattering.

3.2 Volume Interaction Working Group

This group chose to consider a few possibilities for shallow water volume interaction experiments that would make sense given the Chinese and US interests and capabilities. They came up with four leading candidates, the first two of which are perhaps the most interesting. They are described in order.

- Shallow water internal wave experiment - Given the interest of both the Chinese and American scientists in the acoustic scattering by internal waves, this is a natural choice. They would envision this as an experiment composed of one or two vertical acoustic receiving arrays having an acoustic NAVNET and thermistors supporting them, shot sources and moored (tomography type) sources, and thermistor strings and ADCP and/or current meters as oceanographic support. With such an experiment, the investigators could study a wider frequency range than the recent SWARM experiment and also the azimuthal dependence of the scattering. The equipment for such an experiment is readily available between the US and Chinese inventories. Summer conditions and an experiment lasting a few days would be needed. It was suggested that a horizontal array would also be useful for studying coherence issues. Moreover, such an experiment would provide instrumentation that could easily be used simultaneously for bottom interaction, reverberation, and other experiments. The frequency range would be roughly 10 to 3000 Hz.
- Shallow Water Tomography Feasibility Test Experiment - Given the interest of both countries in developing the techniques of tomography in shallow water, this is also a rather natural choice. One could consider modal tomography, scintillation tomography, matched field tomography, etc. The scintillation tomography concept would be especially interesting to explore, in that it has been as extensively examined as modal tomography in shallow water, and holds the possibility of providing the heat flux across a tomographic path length (order 10 to 50 km) if it works well. The down side is that this technique would require two receiving arrays, not one. However, these exist and could be provided. Moored tomography type sources, NAVNETs for the moorings, and appropriate oceanographic support would also be needed. In this case, the support would consist of current meters/ADCPs and thermistor strings across the propagation path, to provide the oceanographic field/fluxes. The frequency range would be 10 to 1000 Hz, and again one would want a data record of a few day's length.
- Fine structure, turbulence, etc., study at higher frequencies - Given that one already has a vertical array in place that can receive higher frequency and is navigated to 1-m accuracy, one could consider looking at higher frequency receptions. Though the array is not navigated well enough to look at spatial coherence at high frequencies, one could still look at temporal coherence. A high frequency source is easy to obtain/make (and in fact the NAVNET balls are adequate to first order!). Also, one could consider putting out a tripod with a simple receiver(s) to look at vertical/horizontal coherence, as has been done by Badiey/Simmen. These are easy experiments to implement and are also of interest to the US and Chinese communities. The physical oceanography support for the Fine Structure would be a bit more problematical, but not impossible. This is a nice, modest size challenge.

- Surface Wave Noise Directional Properties - It was suggested by Prof. Guan that the Chinese might be interested in developing vector hydrophones and deploying an array of such sensors to look at surface wave directional noise. This is not something that many US investigators have pursued. However, David Farmer at IOS has worked with these, and has suitable equipment to monitor the oceanographic environment as well.

Several concerns were raised by this group. One was fish, which could easily have a noticeable effect on transmission and also lure fishermen into the experimental region. The presence of fronts in the suggested experimental area was also questioned.

3.3 Technology Working Group

The Technology Working Group focused on designing a Summer 1996 pilot experiment in the Yellow Sea. This would serve as a test bed for a larger scale experiment to be conducted the following year. It would provide opportunities for early Chinese/US interaction, for organizing necessary diplomatic and logistic agreements and protocols, for assessing equipment interoperability, and importantly, in keeping with this Working Group's charter, it would provide a mechanism for determining technology shortfalls and needs. Planning for such an experiment would also provide a mechanism for continuing the Chinese/US dialog that began at this Workshop.

This early experiment would necessarily involve minimal US supplied equipment and facility support, due simply to the pressure of time. The Chinese already have been planning a small experiment for the Summer of '96, and therefore their arrangements are well along. Further, Chinese logistic requirements are far less.

The pilot experiment itself would focus on combined oceanographic and acoustic measurements with perhaps even a greater emphasis on the former because:

- Several areas might have to be surveyed in order to locate one with the desired bottom and volume conditions (e.g., smoothly layered sub-bottom, strong thermocline, the presence of a front).

- Combined oceanographic studies with acoustic studies is a relatively new experience for the Chinese.

The duration of the experiment will be short, seven to ten days, which is long enough to assess acoustic conditions and equipment operation, but not sufficient to observe many interesting time-varying acoustic phenomena in detail. The follow-on Summer 1997 experiment would be larger scale, more complete and in depth with respect to acoustic measurements, and longer in duration.

This group reviewed the available technologies for conducting shallow water acoustic experiments. The Chinese inventory includes 3 thermistor chains, a 16-element vertical receiving array (5 Hz to 1 kHz), explosive sources usually set at 7 m, 25 m and 50 m depths, and two acoustic sources at 650 Hz and 3.7 kHz. The former source operates at 203 dB, but weighs 400 kg and is not configured in a towbody. It must be lowered at individual stations. The Chinese inventory lacked acoustic releases which would be very desirable for mooring instruments in shallow waters where the danger of damage due to fishing activity is high. The US inventory included sources capable of being towed as well

as those capable of being moored in one position. Acoustic releases are also common in the US.

In addition to the above specialized equipment, the Chinese research vessel EXPERIMENT 3 is equipped (or can be configured) with the usual suite of instruments including bathymetric profilers, sub-bottom profilers, corers, CTDs ADCPs, and so on. There are also three self-recording ADCPs available.

3.4 Oceanography Working Group

This group provided the following recommendations:

- Physical processes and structures related to acoustic propagation, e.g., internal waves, currents, must be observed and studied with measurements by thermistor chains, moored current meters, ADCP, CTD and satellite remote sensing (VIS/IR, SAR, altimetry and scatterometry). Intensive observations shall be carried out concurrently with the acoustic experiment over the area of 20 km spatial scale and at least 2 or 3 days. A background survey over a wider area (3 times the 20 km spatial scale), with CTD and ADCP shall be carried out. Applications of remotely sensed data, numerical modeling, and historical data are important both for the synoptic view of the processes involved and for the support of the in situ measurement planning and executing.
- Geoacoustic parameters (compressional and shear speeds, attenuation, and density vs. depth) shall be derived from observations with seabed coring, acoustic profiler, sidescan sonar, and echo sounder, etc.
- Concentration of suspended material shall be observed with transmisometer and sidescan sonar, etc.
- Literature survey on the geoacoustic study over the area shall be carried out to give some background information.
- At some stage, a small workshop on oceanographic modeling shall be devised to provide an opportunity of comparison of and improvement for the results from different modeling groups.
- Scientists will make the effort of providing equipment such as sidescan sonar and transmisometer and acquisition of microwave remote sensing data (SAR, Alt. and Scatt.).
- A step-by-step implementation plan shall be devised, with enough attention paid to vessel/instrumentation related logistic issues (transportation, timing, etc.).

4 Conclusions

In many ways, the conference achieved what it was set out to do. Major accomplishments of the conference included the establishment of a dialog between Chinese and US scientists who are active in shallow-water acoustics research, assessments of the scientific approaches, logistic issues, and available technology for a comprehensive, collaborative field study, identification of potential experimental sites in the Yellow Sea, and assessment of the environmental conditions. A plan of action was discussed, calling for fostering the dialog that was successfully initiated in this meeting, computer modeling and simulation work in support of the experimental design, and a small-scale, pilot experiment to collect some useful initial data and to provide a learning experience on how to work together in the field.

This meeting held at the Naval Postgraduate School represents the very first joint USA-China Conference on Shallow-Water Acoustics. As a follow-on to further the dialog between the Chinese and US underwater acoustics research communities, an international conference on Shallow-Water Acoustics in Beijing, China, in April, 1997 is being jointly organized by Georgia Institute of Technology, the Naval Postgraduate School and the Chinese Academy of Sciences. A pilot experiment in the Yellow Sea has also been conducted involving researchers from the Applied Research Laboratory at University of Washington, Georgia Institute of Technology and the Chinese National Laboratory of Acoustics. Our goal is now to develop a comprehensive, joint USA-China experiment in the Yellow Sea. Such an experiment will focus on studying the physics of sound propagation and scattering in shallow water, supported by detailed observations and characterizations of the environment. In view of the findings and recommendations made by the four working groups on experimental objectives, approaches, available technology and environmental conditions, it seems possible to design a large-scale experiment addressing both volume and boundary-interaction research topics.

5 Acknowledgements

It is with great pleasure that we gratefully acknowledge the assistance of Susan Wade and Rob Bourke in the organization, administration, and flawless excecution of the Workshop. We also gratefully acknowledge the working group leaders; George Frisk, Jin Guoliang, Jim Lynch, Guan Dinghua, Zhang Renhe, Bob Spindel, Shi Ping, and Bill Jobst. Their collective leadership was essential to the Worshop's convergence. Finally, the workshop would not have been possible without the creativity and financial support of Jeff Simmen of the Office of Naval Research.

APPENDIX A

ONR US/China Conference on Shallow Water Acoustics

Agenda

Tuesday, 19 December 1995

0800-0830	Opening Remarks: Adm. Evans - Welcome Ching-Sang Chiu - Goals and Objectives Warren Denner - Administrative Details
0830-1030	Recent & Planned U. S. Experiments in Shallow Water - Jim Lynch Recent & Planned Chinese Experiments in Shallow Water - Zhang Renhe Laboratory Measurement on Acoustic Propagation - Shihong Zhou
1030-1100	Coffee Break
1100-1200	Modeling Shallow Water Acoustic Propagation - Zhang Renhe Modeling Shallow Water Acoustic Propagation - Bill Kuperman
1200-1300	Lunch
1300-1500	Bottom Interaction Research in the US - George Frisk Bottom Interaction Research in China - Jin Guoliang, Guan Dinghua
1500-1530	Coffee Break
1530-1730	Volume Interaction Research in the US - Nick Makris Volume Interaction Research in China - Guan Dinghua, Yan Jin, Qui Xinfang

Wednesday, 20 December 1995

0800-0830	Opening Remarks - Jeff Simmen
0830-1030	Oceanography in Support of Shallow Water Acoustics - Gan Zijun Oceanography in Support of Shallow Water Acoustics - Bill Jobst
1030-1100	Coffee Break
1100-1200	Remote Sensing Research in China - Shi Ping
1200-1300	Lunch
1300-1500	Technology for Shallow Water Acoustics Research - Li Ping Technology for Shallow Water Acoustics Research - Bob Spindel
1500-1530	Coffee Break
1530-1700	Possible Research Issues in Shallow Water Acoustics - All

Thursday, 21 December 1995

0800-0830	Opening Remarks - Ching-Sang Chiu and Zhang Renhe
0830-1030	Working Group Meetings on Research Issues
1030-1100	Coffee Break
1100-1200	Working Group Meetings on Research Issues
1200-1300	Lunch
1300-1500	Working Group Reports
1500-1530	Coffee Break
1530-1700	Wrap-up

APPENDIX B

ONR US/China Conference on Shallow Water Acoustics

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APPENDIX C

ONR US/China Conference on Shallow Water Acoustics

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Volume Interaction Working Group:
Lynch(Co-Chair)
Guan(Co-Chair)
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Technology Working Group:
Zhang(Co-Chair)
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Spindel(Co-Chair)
Ali

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